April 2013

Improving the Tegra 4 Use Case Model

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A Major Qualifying Project submitted to the Faculty of
WORCESTER POLYTECHNIC INSITIUTE in partial fulfillment of the
requirements for the degree of Bachelor of Science

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Date:
March 2013

[Some materials have been removed due to confidentiality]

Abstract

Mobile devices are becoming smaller in size, longer in battery life, and faster in processing speed. NVIDIA, a company in computing graphics, developed Tegra, a line of mobile processors, to keep up with this trend. During production of a Tegra processor, NVIDIA utilizes a use case model to predict the performance of the processor before its silicon production. Such performance is quantified as the least amount of bandwidth or running frequency the processor needs to complete a task. The overall goal of this project is to improve the accuracy of the Tegra 4 use case model. This goal is split into two tasks. In the first task, the predictions of the model are compared with the measurements taken from Tegra 4 silicon. Discrepancies found in these comparisons are analyzed, and errors discovered in the model are reported. In the second task, a set of experiments is conducted for a gaming use case, varying the CPU, GPU and memory controller frequencies and seeing its effect on frame rate. In this task performance is quantified as frame rate. The relationship found between the frequencies and frame rate will help incorporate more functionality into the gaming use case model. The results of our project assist in improving the use case model, which aids in the development of future Tegra processors.

Executive Summary

In 2008, the NVIDIA Corporation introduced Tegra, a line of processors for mobile devices. NVIDIA's customers often request bandwidth and frequency requirements of the newest Tegra processor in development. To accommodate such requests, NVIDIA implemented a use case model to predict the bandwidth and frequency values of the Tegra 4 processor given input use cases. Use cases represent the various ways a consumer may be using the final product. The model was built based on some assumptions, many of which are incorrect, which generated predictions that do not match up with measurements from post-silicon testing. In addition, the model lacks sufficient data to accurately predict gaming use cases. Therefore, the goal of this project is to improve the performance predictions in the use case model for the Tegra 4 processor.

We met the assigned goal by completing two separate tasks: post-silicon validation and gaming performance statistics gathering. For the post-silicon validation task, we found use case model input parameters for three different use case categories: UI & Wallpaper, video playback, and gaming. The use case model gave frequency and bandwidth predictions for all our use cases. On our Tegra 4 development board, we performed systematic measurements for each use case, and compared the measurements with the model's predictions. We analyzed and provided detailed explanations for each mismatch observed. For gaming performance measurements task, we investigated in how different CPU, GPU and memory controller frequency combinations within the Tegra 4 affect the frame rate for gaming use cases. Using our measurements, we plotted out the relationship between the frame rate and CPU frequency for certain pairs of GPU and memory controller frequency values. As side products of our project, we also implemented many tools and scripts to

facilitate our measurements. These tools and scripts served to streamline the data collection process.

The results of the post-silicon validation task show that the use case model accurately models the frequency and bandwidth values for the internal and HDMI display controllers within the Tegra 4. However, the use case model failed to give accurate predictions for many other modules such as the CPU, GPU, and video decoder. For each mismatch observed, we investigated the causes for each discrepancy, which included the model’s inaccurate assumptions, defects of the data measurement tools, and unexpected Tegra software behavior. Depending on the reason for the mismatch, we improved the measurement tools, filed bugs, or consulted with the appropriate teams to address the issues. The results of gathering gaming performance statistics showed that the memory controller frequency was the limiting factor in frame rate for Riptide, the game we did our measurements on.

Our work was helpful to NVIDIA's Mobile System Architecture Team in several ways. Firstly, we discovered many mismatches between the use case model’s predictions and the actual measurements on the development board. Such feedback helped to improve the model by providing realistic measurement data, finding false assumptions, and identifying unexpected software behavior. Our gaming performance measurements also helped the team build more accurate gaming models by showing the relationship between CPU, GPU, memory controller frequencies and the frame rate, an important benchmark for gaming performance. Lastly, many of the tools and scripts we implemented were helpful in streamlining the data collection process for future use.

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